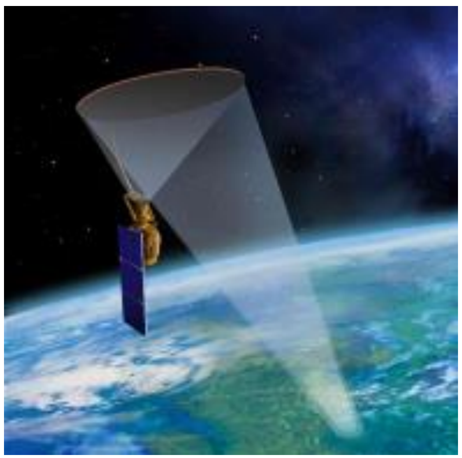
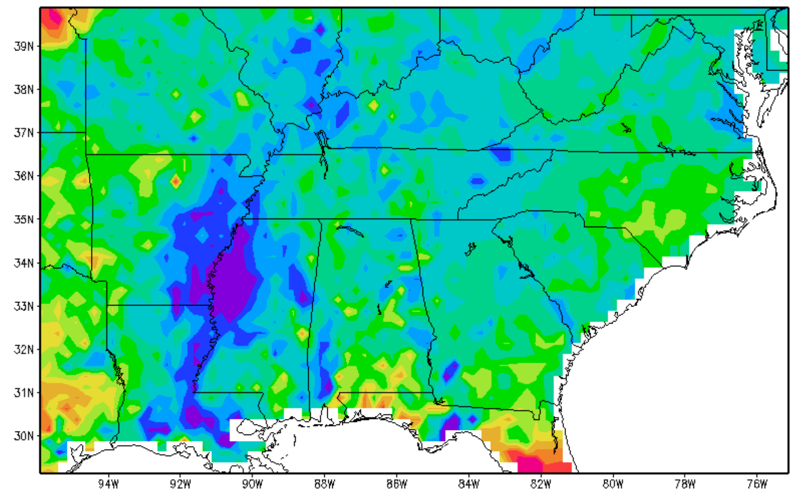
SMOS soil moisture data assimilation in the NASA Land Information System: Impact on LSM initialization and NWP forecasts





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29th Conference on Hydrology

AMS Annual Meeting

6 Jan. 2015, Phoenix, Arizona

Goals

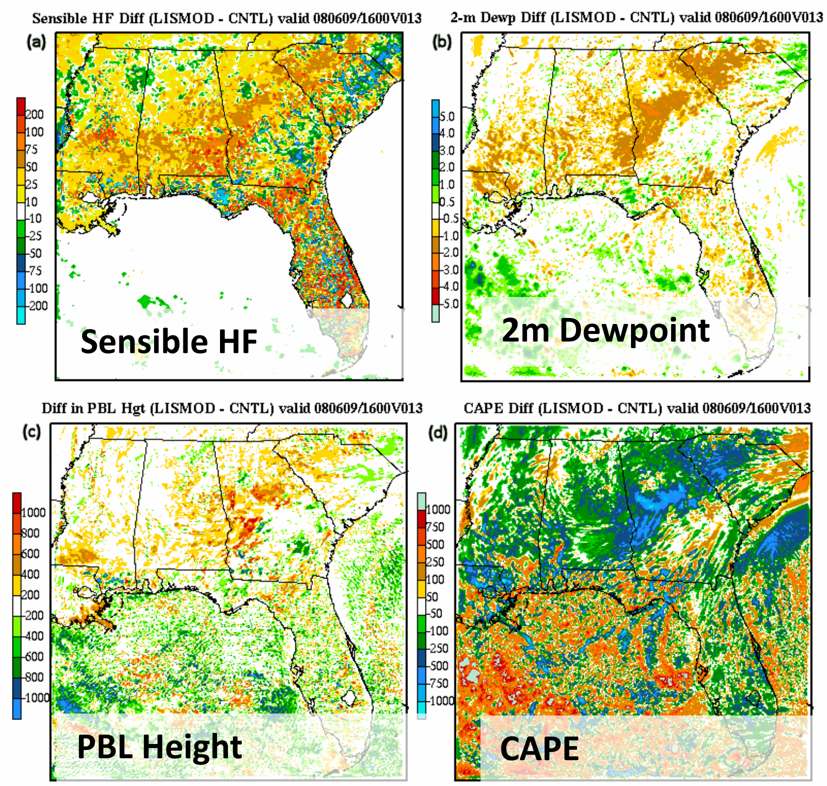
Soil Moisture Data Assimilation

Forecast Challenge

– Available moisture affects humidity, sensible/latent heating, diurnal heating rate, and convection

Objective

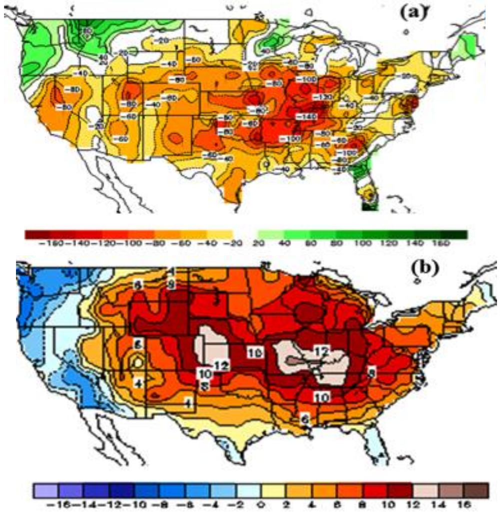
- Improve soil moisture estimates for regional NWP applications and situational awareness
  – Improve LIS soil moisture by assimilating satellite retrievals
  – Use LIS output to initialize NWP



Impact of using high-resolution LIS boundary conditions in WRF (rather than NAM fields). From Case et al. 2008

Other Applications

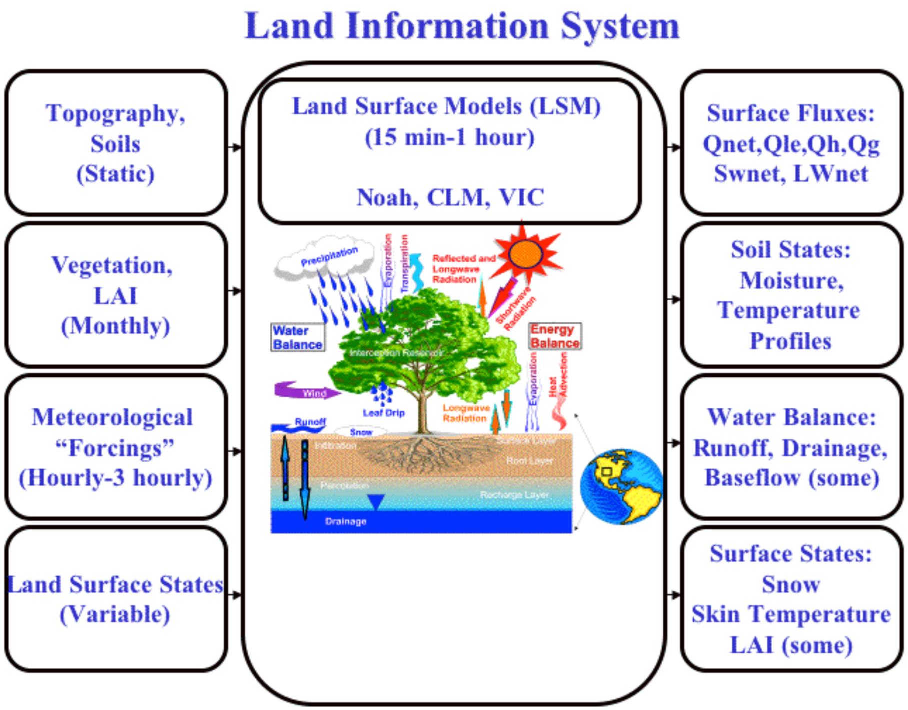
- Drought/Heat Wave Monitoring
- Flood Forecasting
- Streamflow prediction
- Public health

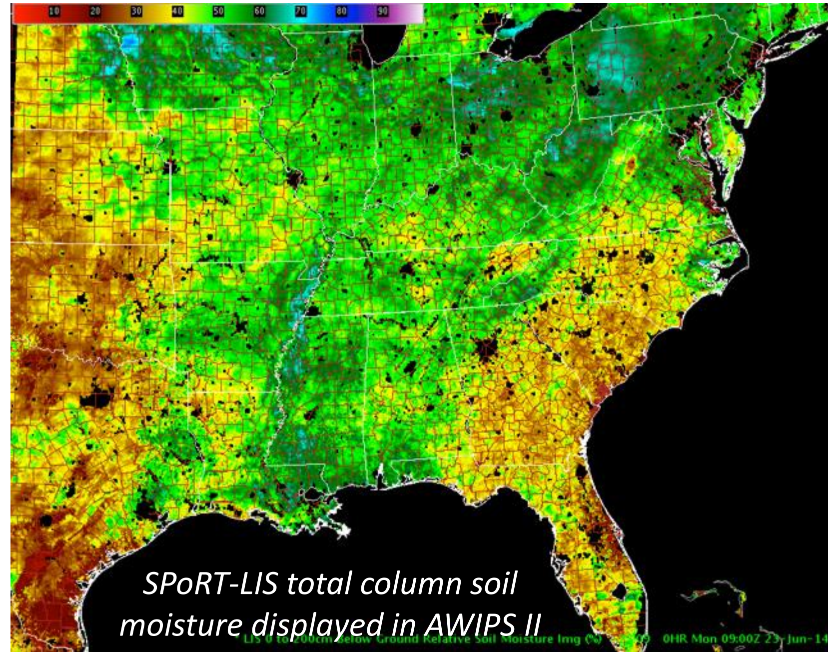


Temperature anomalies

Soil moisture anomalies

Operational SPoRT Land Information System (LIS)



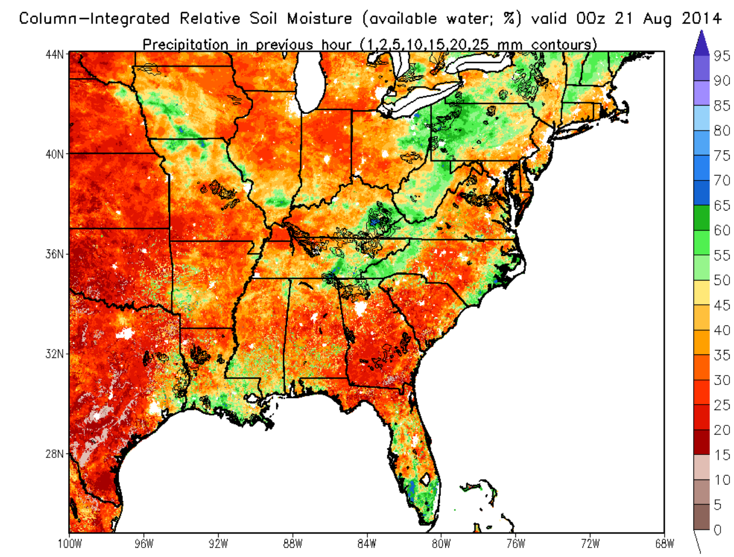


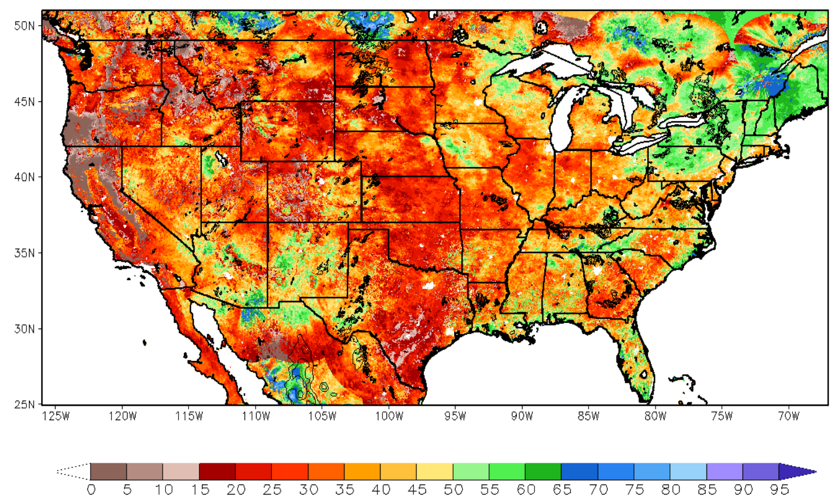
SPoRT-LIS total column soil moisture displayed in AWIPS II

- **NASA LIS used to perform long-term integration of Noah Land Surface Model (LSM) updated in real-time**
  - Precipitation forcing: NLDAS-2, Multi-Sensor, Multi-Radar (MRMS), and GFS forecast
  - Vegetation coverage/health: Green Vegetation Fraction (GVF) from MODIS (VIIRS 2014)
  - Forecast data allows use of latent observations while retaining their impact on later cycles
- **Assimilation of soil moisture should give even more accurate LSM soil moisture fields**
- **Used for situational awareness and local modeling**

SPoRT-LIS Real-time Configurations

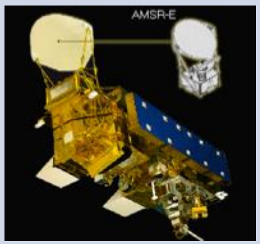
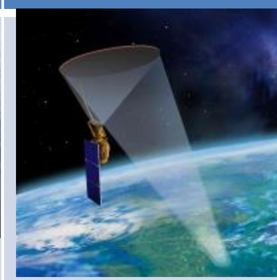
- Running Noah LSM at ~3-km resolution with ***real-time MODIS GVF***
- "Operational" Southeast U.S. domain
  - Driven by NLDAS-2/Stage IV precip
  - Data used for both local modeling in WRF/EMS and display in AWIPS II
  - Used in current LIS assessment
- Experimental CONUS domain
  - Interest from SPoRT western partners
  - Driven by NLDAS-2/**MRMS*** precip





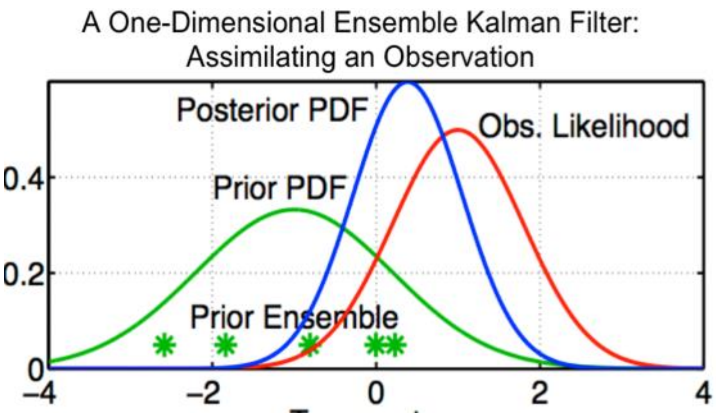
***Multi-Radar Multi-Sensor 1-km QPE**

Soil Moisture Instruments

Name	AMSR-E	**SMOS** Soil Moisture and Ocean Salinity	**SMAP** Soil Moisture Active/Passive		
					
Agency	NASA/JAXA	ESA	NASA		
Launch		2009	Nov. 2014		
Orbit	Polar	Polar	Polar		
Sensor Type	Passive	Passive	Passive	Active	Combined
Frequency	6.9 GHz (C-band)	1.4 GHz (L-band)	1.41 GHz	1.2 GHz	
Resolution	56 km	35-50 km	36 km	**3 km**	9 km
Accuracy	6 cm^3/cm^3	**4 cm^3/cm^3**	**4 cm^3/cm^3**	6 cm^3/cm^3	**4 cm^3/cm^3**

Data Assimilation with EnKF

- Use Ensemble Kalman Filter within LIS to assimilate satellite soil moisture retrievals into the Noah 3.2 LSM
- EnKF combines the model **background** and **observations** to make **analyses**
  - Relative weighting is controlled by the specified **observation error** and by the **ensemble spread**
- Implemented EnKF assimilation of SMOS L2 data
  - QC based on model state and data flags for precipitation, RFI, data quality, frozen soil, snow cover, and high vegetation
  - Empirically tuned run-time settings including perturbations, number of ensemble members
  - Bias correction by CDF Matching
  - Capability of implementing landcover-dependent correction.



- Assimilation is 1-D (each grid cell independent). Observations can be spread over several grid cells for high-resolution model runs.
- Planned for use in near-real-time SPoRT LIS

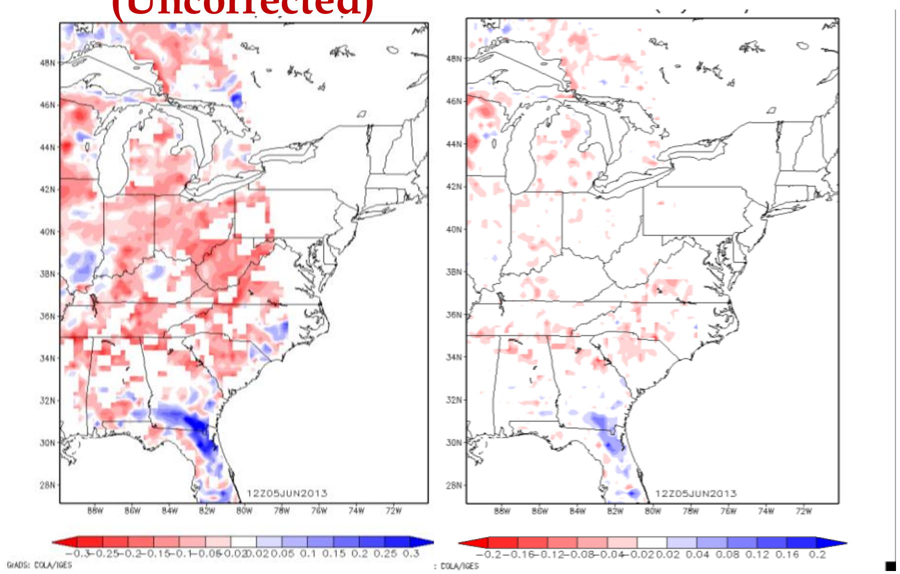
Figure from J. Anderson, NCAR.

Bias Correction

- Initial tests had large dry bias in observations, so that only extreme rain events had correct sign.
- Discussions with other researchers confirmed need for bias correction

Innovations (Uncorrected)

Increments

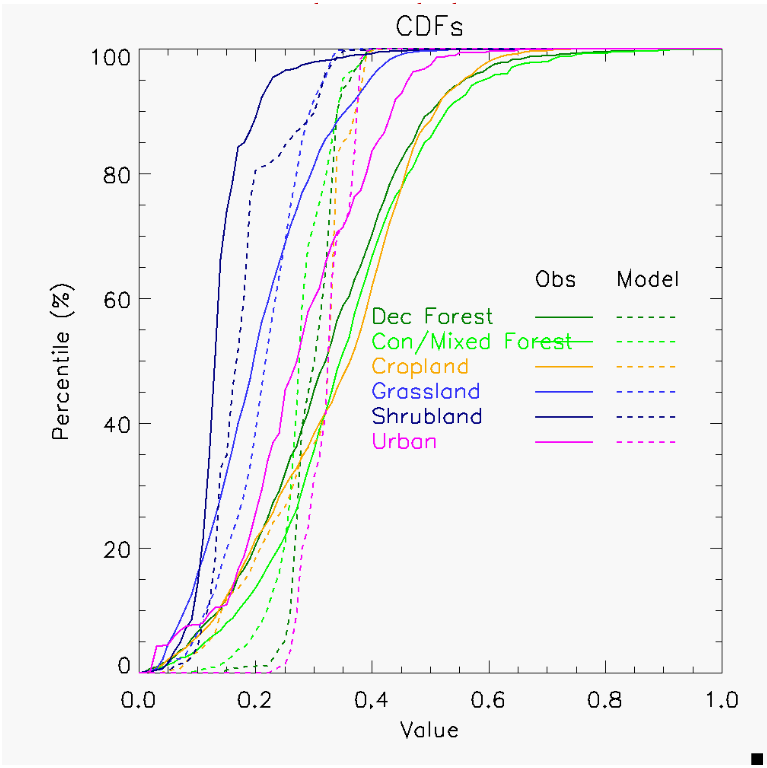


Uncorrected innovations (observations minus model) and increments. Red=dry bias in retrievals.

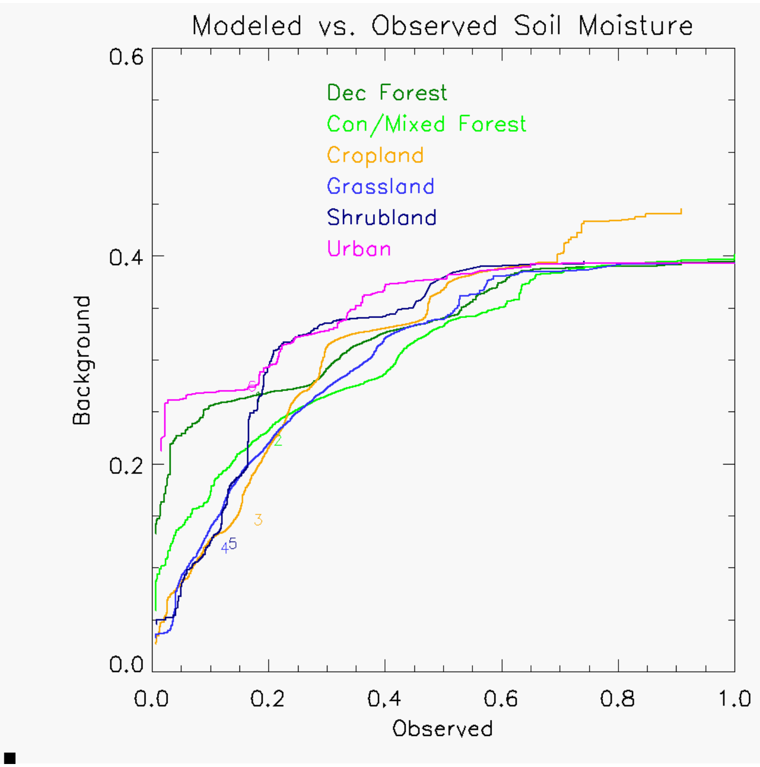
- Implemented CDF matching correction for SMOS retrievals.
- Assimilating retrievals (not radiances) lets us use established methodology

Bias Correction

CDFs of Soil Moisture Observations

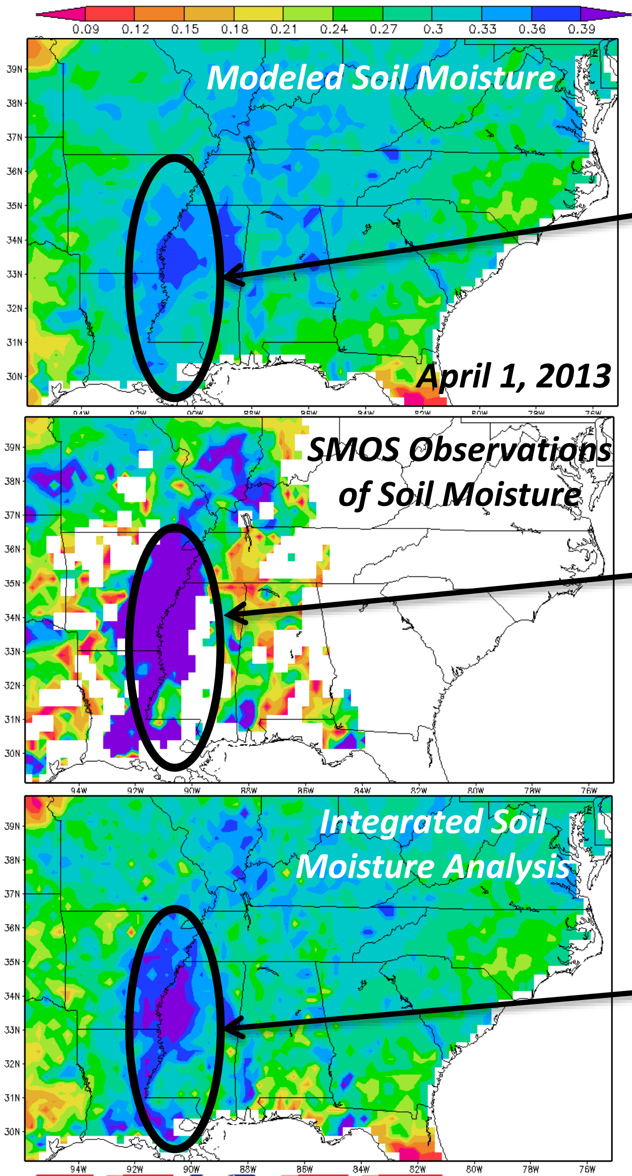


Correction Curves



- **LIS can apply point-by-point correction curves. To increase the background dataset size, we are aggregating points by landcover type. We will also explore correction at each point and aggregating by soil type.**
- **In general, observations are drier than the model but have a higher dynamic range.**

Irrigation Case Study

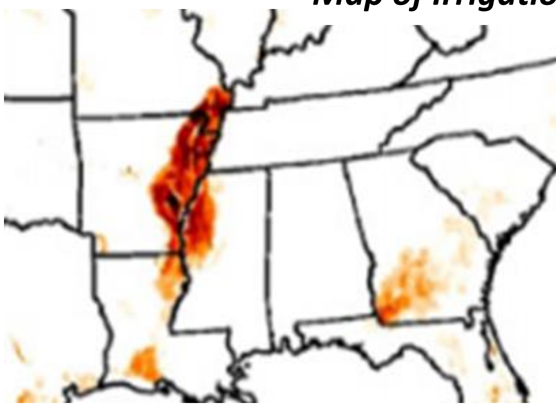


Model soil moisture concentration forced only by precipitation and misses magnitude of irrigation-saturated MS Valley

SMOS observes irrigated fields

Blended analysis of model and observations better represent irrigated area and should result in improved weather and hydrologic modeling

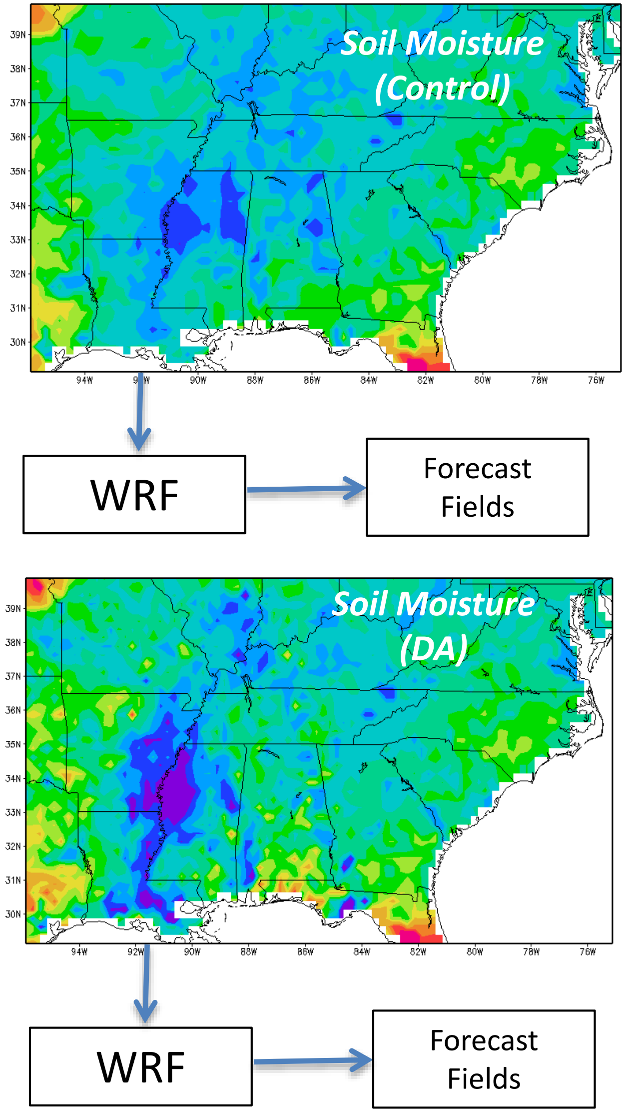
Map of Irrigation Areas



From U. of Frankfurt-FAO (Ozdogan 2001)

- Test Impact on NWP using coupled LIS-WRF
- Implications for regional climate modeling
  - Impacts of changing land-use, precipitation patterns

Case Study: Irrigation Impact



- Irrigation scenario makes a good case study
  - Forcing data is inaccurate due to irrigation
  - Demonstrate benefit of satellite DA
  - DA impact should also be enhanced in areas with with sparse observation networks (mountainous terrain, underpopulated areas, developing countries, etc.)
- Test impact on NWP using coupled LIS-WRF
  - Validate soil moisture values
  - Examine impact on NWP
  - Verify NWP forecasts
  - Impact on boundary layer for a quiescent day
  - Active convection case
  - Validation over a longer time period
- Implications for regional climate modeling
  - Impacts of changing land-use, precipitation patterns

Current and future plans

- Validate analyses
  - TAMU North American Soil Moisture Database
- Test Impact of assimilating SMOS retrievals on NWP using coupled runs in NU-WRF
  - Impact on boundary layer for a quiescent day
  - Active convection case
  - Validation over a longer time period
  - Look at both sensitivity and forecast accuracy
- Assimilate active/passive blended product from SMAP; higher spatial resolution (9 km) should improve local-scale processes

Questions?